Pet food processing

some nutritional considerations

Wouter Hendriks

WAGENINGEN UNIVERSITY
WAGENINGEN UR

Universiteit Utrecht

Content

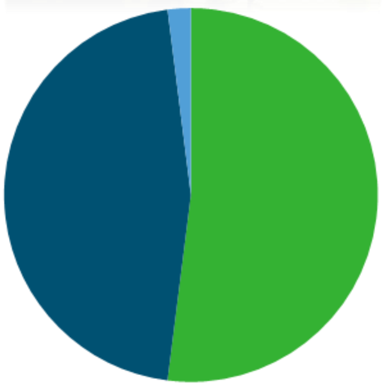
- Importance of protein for cats and dogs: recent new findings
- Processing and the Maillard reaction in pet foods
- Processing and protein quality of pet foods
- Protein and amino acid digestibility in dogs

Recent new findings

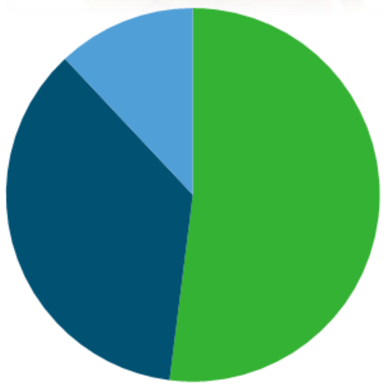
Self-selection experiments and feeding ecology studies show:

- Close agreement in nutrient intake of domestic and wild cats
  - High protein, high fat, low carbohydrate
- Dogs and wolves prefer/consume low carbohydrate diets

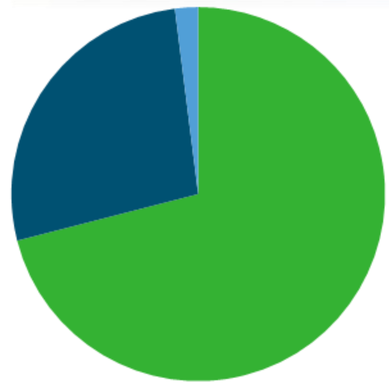
Recent new findings



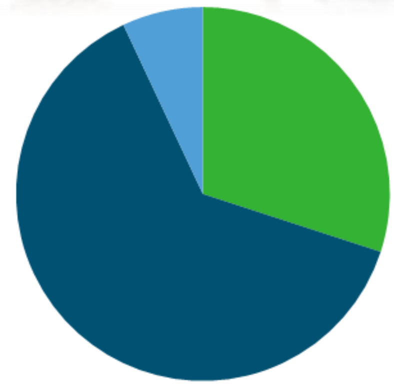
Wild 52:40:7



Self-selection 52:35:12



Wild



Self-selection

Protein
Lipids
Carbohydrates

Hagen-Plantinga et al. (2012) Brit J Nutr
Hewson-Hughes et al. (2011) J Exp Biol
Bosch et al. (2014) Brit J Nutr, in press
Hewson-Hughes et al. (2013) Behav Ecol

Carnivore or omnivore?

Like 44 | Tweet 1 | +1 0 | Share 12

Dogs are classified as members of the family Canidae and the order Carnivora, but this does not necessarily translate to behavior, anatomy or feeding preferences.

- Wolves attack plant-eating animals, but one of the first parts they consume is the stomach contents and the viscera of those animals.[1]

- Coyotes eat a variety of foodstuffs including small mammals, amphibians, birds, fruits

- Panda bears are also members of the order Carnivora, but they are herbivores who primarily consume bamboo leaves.

higher nutritional requirement for taurine (an amino acid), arachidonic acid (a fatty acid), and

Key points

- Coyotes eat a variety of foodstuffs including small mammals, amphibians, birds, fruits and herbivore feces.

vitamins and can create their own arachidonic acid from vegetable oils.

- Dogs have a small intestine that occupies about 23 percent of the total gastrointestinal volume, which is consistent with other omnivores; the small intestine of cats occupies only 15 percent.[3,4]

- Dogs can digest almost 100% of the carbohydrates they consume.[2]
- Dogs have a small intestine that occupies about 23 percent of the total gastrointestinal volume, which is consistent with other omnivores; the small intestine of cats occupies only 15 percent.[3,4]
- Dogs can create vitamin A from betacarotene found in plants.

Confusion in their conclusion

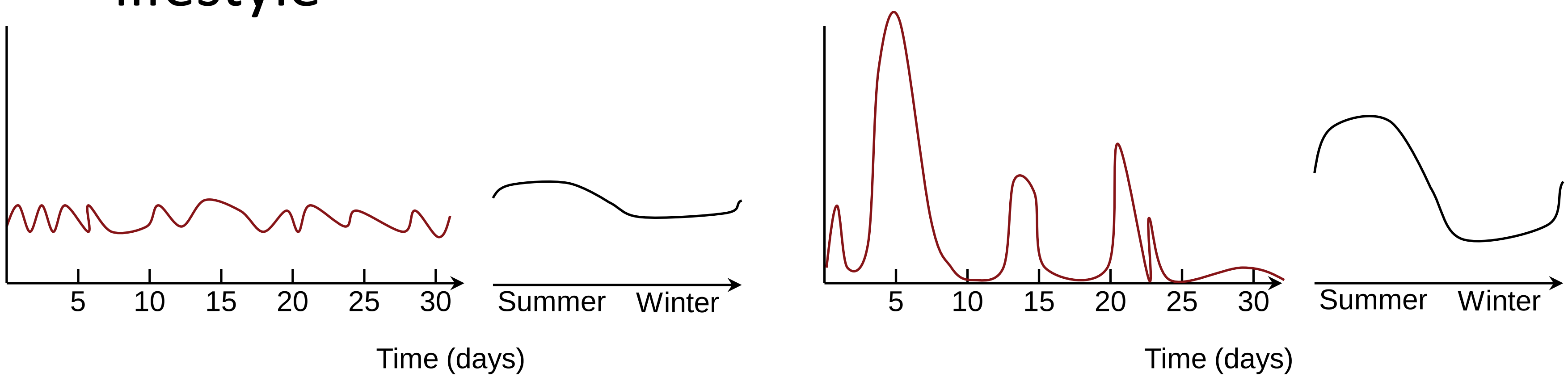
Some folks have come to the erroneous conclusion that dogs must be carnivores because they fall under the order Carnivora. A close look at the anatomy, behavior and feeding preferences of dogs shows that they are actually omnivorous — able to eat and remain healthy with both animal and plant foodstuffs.

[1] Lewis L, Morris M, Hand M. Small Animal Clinical Nutrition, Ed. 4. Topeka, KS, Mark Morris Institute, 2000;294-303,216-219.
[2] Walker J, Harmon D, Gross K, Collings G. Evaluation of nutrient utilization in the canine using the ileal cannulation technique. J Nutr. 1994; 124:2672S-2676S.
[3] Morris JG, Rogers QR. Comparative aspects of nutrition and metabolism of dogs and cats, in: Nutrition of the dog and cat, eds. Burger IH, Rivers JPW, Cambridge, UK, Cambridge University Press, 1989;35-66.
[4] Ruckebusch Y, Phaneuf L-Ph, Dunlop R. Feeding behavior in: Physiology of small and large animals, B.C. Decker, Inc. Philadelphia, PA, 1991;209-219.

Petfood Forum Asia

Recent new findings

- Wolves are adaptive carnivores due to feast-famine lifestyle



Protein (and protein quality) is becoming more important in optimal nutrition of domestic cats and dogs

The Maillard reaction

- Non-enzymatic browning reaction
- Involves a reducing sugar and amino acids (protein)

  Sugars: glucose>maltose>lactose>fructose

  Amino acids: free amino acids and protein bound esp. Lys, Arg, His, Trp
- Provides flavour/colour to foods
- Occurs during processing and storage of pet foods and pet food ingredients

Louis-Camille Maillard (1878 - 1936)
Photographed in his laboratory *ca* 1915

1912 – 1916:
He published 8 papers on his observations of colour changes on mixing amino acids and sugars.
No one else took much interest in the reaction until 1950s

John Hodge: 1914 -1996

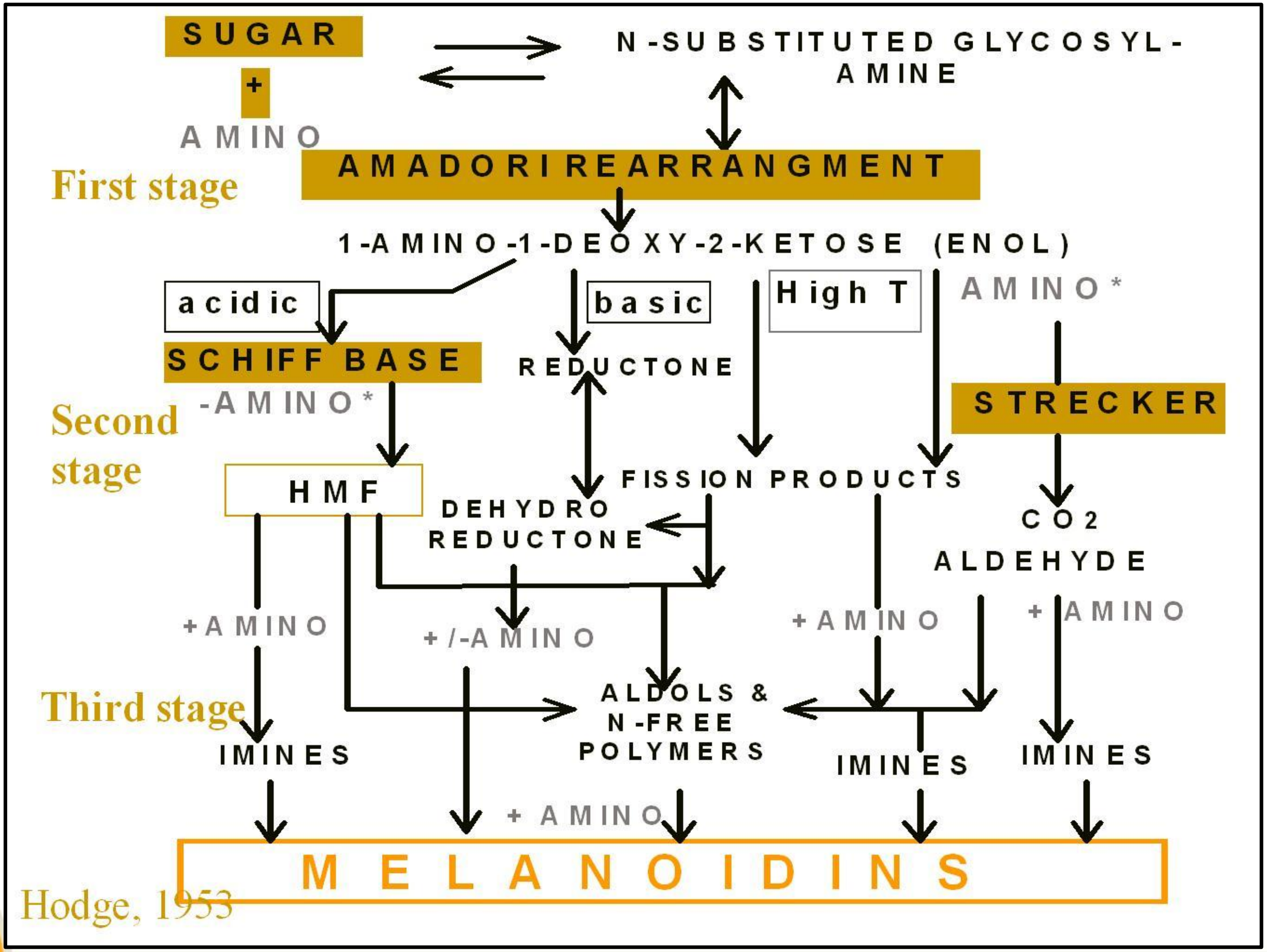
- Chemist at USDA Labs in Illinois (1941 – 1980)
- His proposed mechanism for the chemistry of non-enzymic browning (or the "Maillard Reaction") is largely unchanged after 60 years.

Citations since 1970

Paper	Citations
Hodge, J. E. Chemistry of browning reactions in model systems. *J. Agric. Food Chem.* 1953, **1**: 928-943.	**890**
Maillard, L. C. Action des acides amines sur les sucres: formation des melanoidines par voie methodique. *Compt. Rend.* 1912, **154**: 66-68.	**634**

Maillard-**Hodge** Reaction?

Maillard/Hodge reaction



The Maillard reaction

- Physiological effects
  - Delayed protein turn-over and tissue repair
  - Binding to AGE Receptor
    - Oxidative stress
    - Vasoconstriction
    - Inflammatory responses
- Contribute to pathogenesis of age-related diseases e.g. diabetes, renal/cardiovascular and neurodegenerative diseases,

Pet food processing

Pelleting

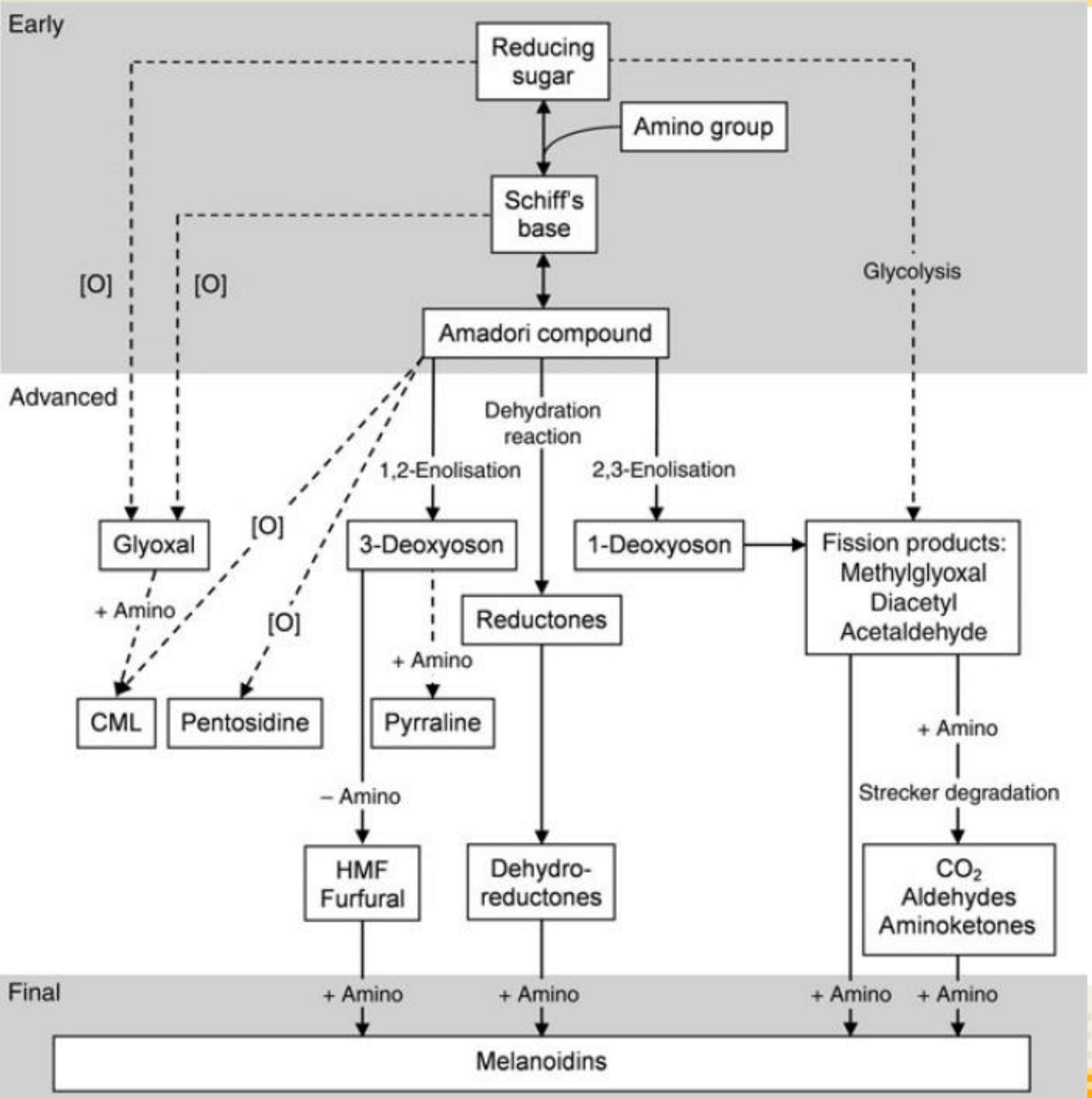
- 60 – 90 °C
- 30-45 sec
- Pressed through die
- Compression

Extrusion
+
Drying

- 80 – 200 °C
- 10-270 sec
- High pressure
- Expansion

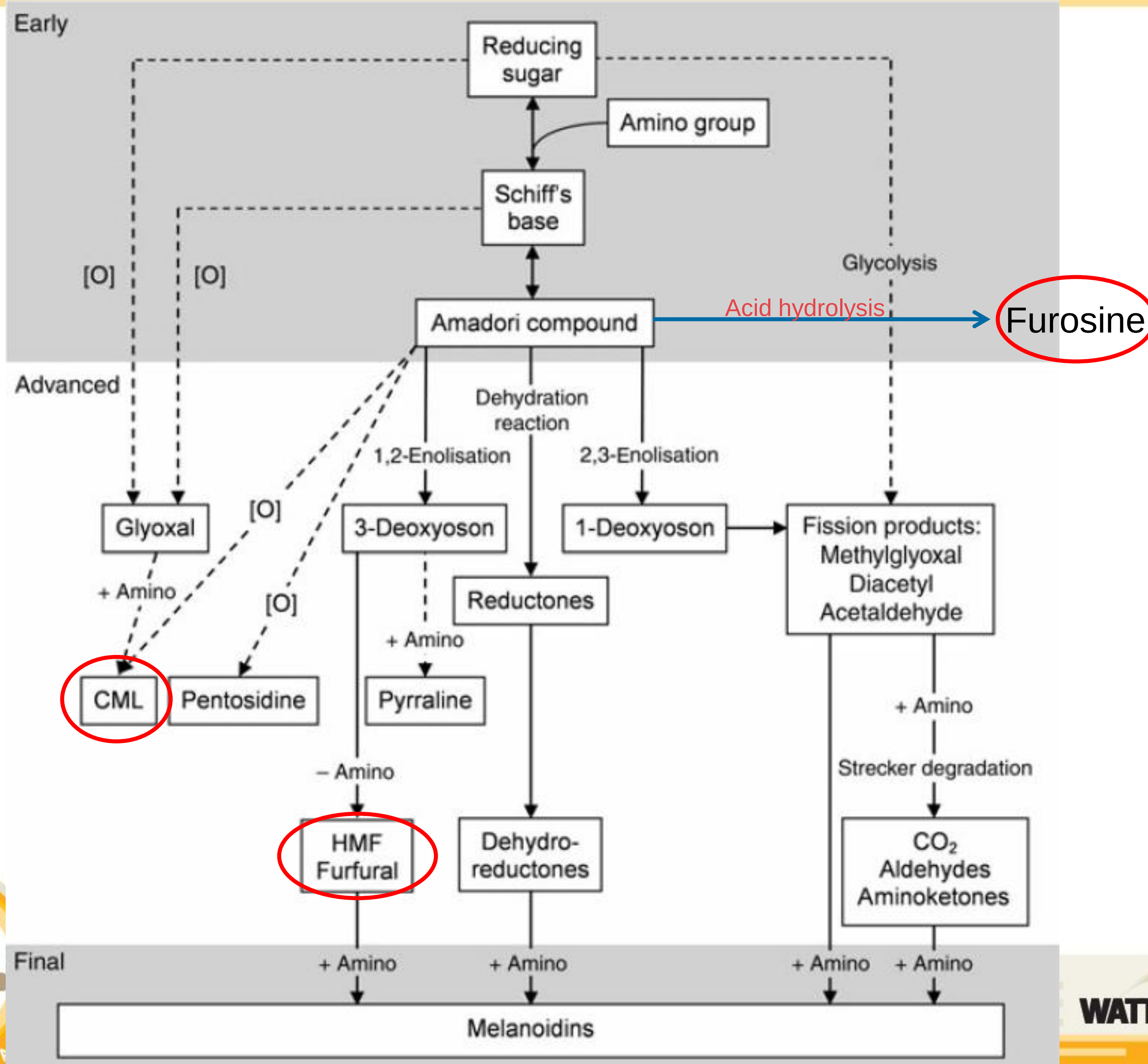
Canning
or
sterilisation

- 121 - 139°C
- 10 -120 min
- High pressure
- Sterilising


Early
Reducing sugar
Amino group
Schiff's base
[O]
[O]
Glycolysis
Amadori compound
Advanced
Dehydration reaction
1,2-Enolisation
2,3-Enolisation
[O]
Glyoxal
3-Deoxyoson
1-Deoxyoson
Fission products: Methylglyoxal Diacetyl Acetaldehyde
+ Amino
[O]
Reductones
+ Amino
CML
Pentosidine
Pyrraline
+ Amino
Strecker degradation
– Amino
HMF Furfural
Dehydro-reductones
CO_2 Aldehydes Aminoketones
Final
+ Amino
+ Amino
+ Amino
+ Amino
Melanoidins

Markers of the Maillard reaction

- Furosine
    - originates from the hydrolysis of ε-N-deoxyketosyllysine
- Carboxymethyllysine (CML)
- Hydroxymethylfurfural
- Difference between total and reactive lysine
    - Affects nutritional value


Early
Reducing sugar
Amino group
Schiff's base
[O]
[O]
Glycolysis
Amadori compound
Acid hydrolysis
Furosine
Advanced
Dehydration reaction
1,2-Enolisation
2,3-Enolisation
[O]
Glyoxal
3-Deoxyoson
1-Deoxyoson
Fission products: Methylglyoxal Diacetyl Acetaldehyde
+ Amino
[O]
Reductones
+ Amino
CML
Pentosidine
Pyrraline
+ Amino
Strecker degradation
– Amino
HMF Furfural
Dehydro-reductones
CO_2 Aldehydes Aminoketones
Final
+ Amino
+ Amino
+ Amino
+ Amino
Melanoidins

Maillard reaction in pet foods?

J. Agric. Food Chem. **1983**, *31*, 1373–1374 **1373**

A Simple and Rapid High-Performance Liquid Chromatographic Procedure for Determination of Furosine, Lysine-Reducing Sugar Derivative

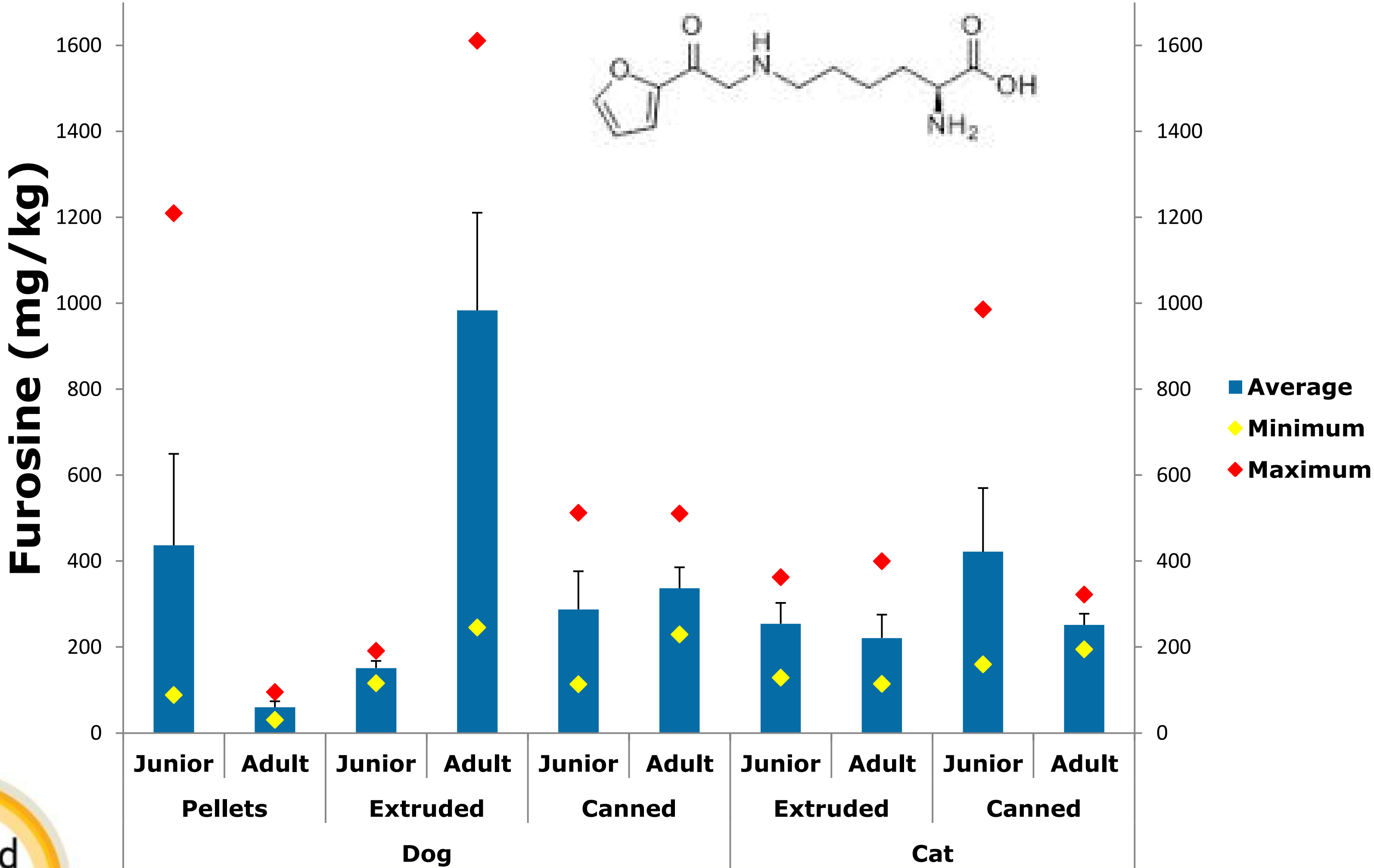
- Only one report showing the presence of furosine
- Storage increases [furosine]

Table II. Furosine Level in Acid Hydrolysates of Storage Samples

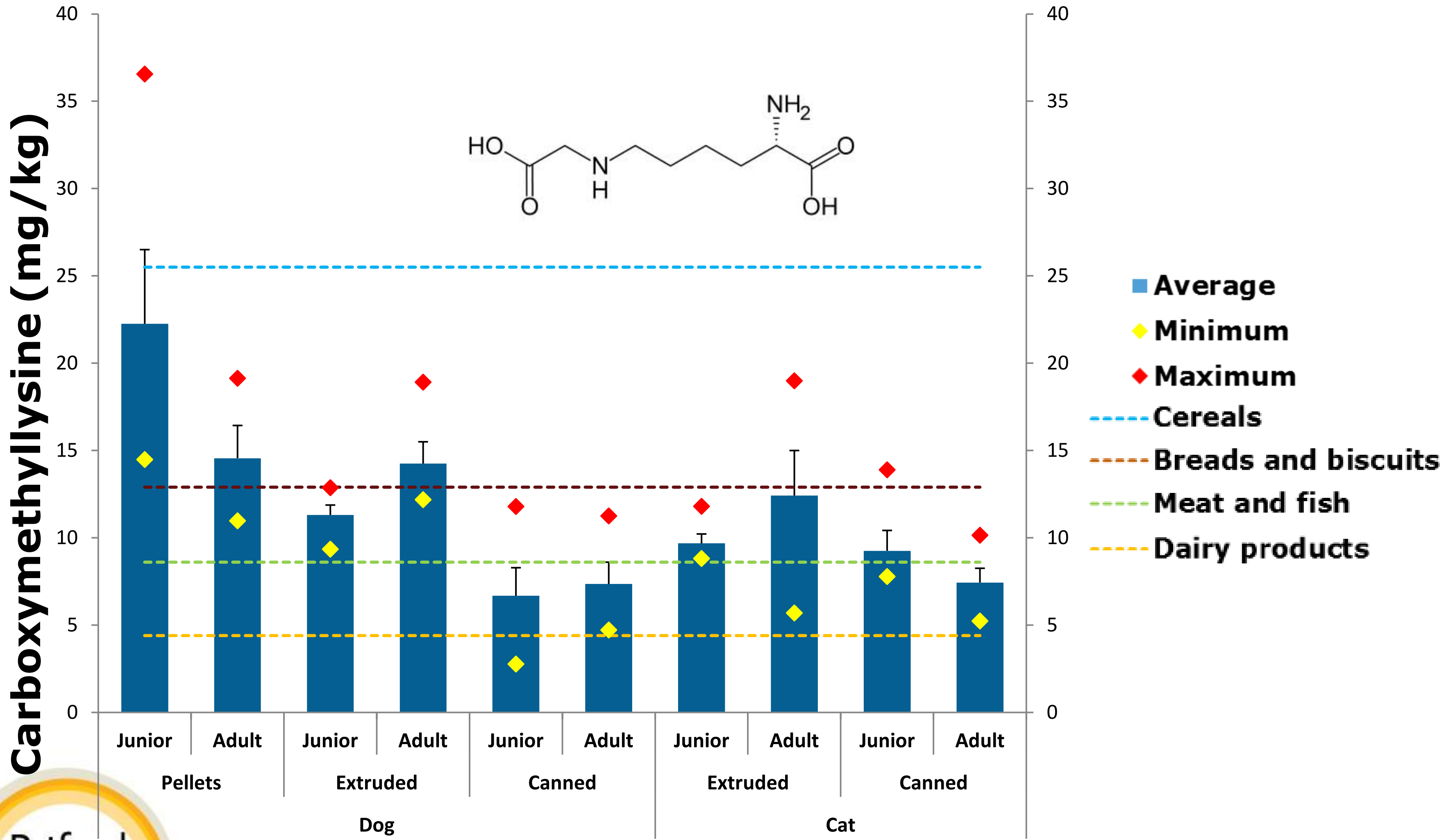
samples	storage conditions	furosine level, mg/g
nonfat dry milk	control	4.83
		4.81
	10 weeks at 45.0 °C	11.58
		11.28
semimoist cheese sauce	4 weeks at 4 °C	0.07
	4 weeks at 45.0 °C	0.14
		0.15
instant dry cheese sauce	8 weeks at 29.4 °C	1.20
		1.15
	8 weeks at 37.8 °C	2.49
		2.54
	8 weeks at 45.0 °C	4.42
		4.69
powdered meal replacer (chocolate flavor)	control	1.84
		1.84
	1 month at 45.0 °C	3.02
		3.06
	3 months at 45.0 °C	4.47
		3.81
	4 months at 45.0 °C	4.84
		4.74
	5 months at 45.0 °C	4.36
		4.32
dry gravy	90 weeks at 22.2 °C	0.42
		0.40
diet bar	control	2.11
		2.15
	55 weeks at 22.2 °C	13.87
formed meal bar	control	0.61
		0.54
	14 weeks at 37.8 °C	5.50
		5.77
dry dog food	control	0.91
	12 weeks at 22.2 °C	1.53
		1.51
	12 weeks at 37.8 °C	3.17
		3.21

Petfood Forum Asia

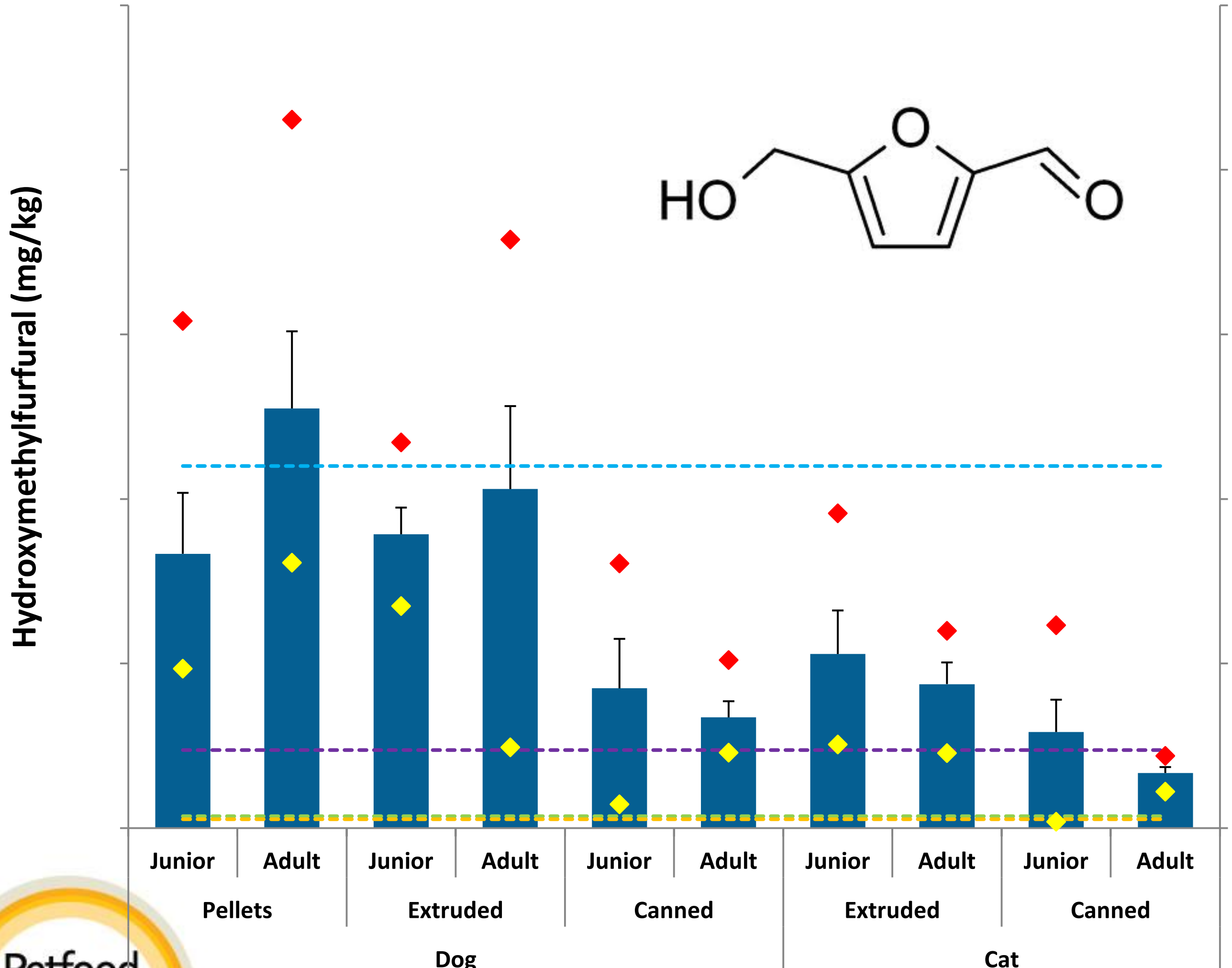
Furosine in pet foods (n=64)



CML in pet foods (n=64)



HMF in pet foods (n=64)

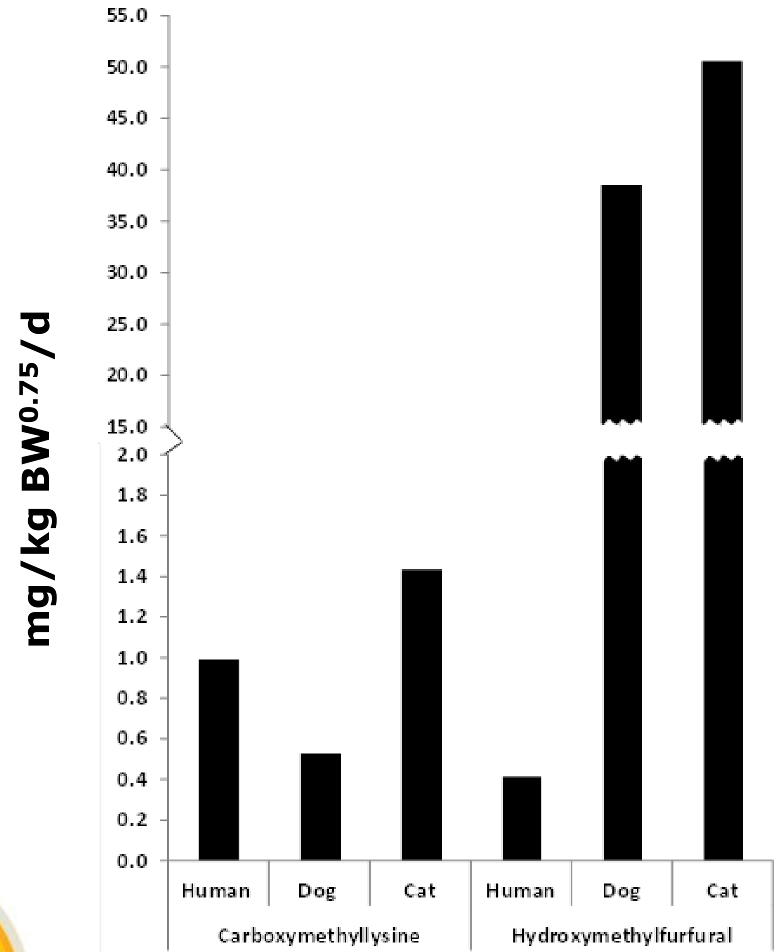


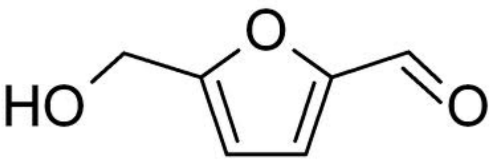
(Arribas-Lorenzo *et al.* 2010; Murkovic & Pichler, 2006; Husøy *et al.* 2008; Rufian-Henares & Cueva, 2008)

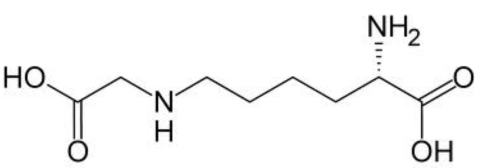
Daily MRP intake

Cats and dogs *vs.* humans

Dog = 20 kg
Cat = 4 kg
Human = 70 kg







Lysinoalanine in petfoods

- Amino acid formed during heat or alkali treatment

Cysteine + serine → hydroalanine

\+

lysine → lysinoalanine

		Dog (mg/kg dry matter)						Cat (mg/kg dry matter)			
		Extruded		Canned		Pelleted		Extruded		Canned	
		Junior	Adult	Junior	Adult	Junior	Adult	Junior	Adult	Junior	Adult
LAL	Mean	7.76±0.63	6.41±1.19	5.80±0.64	7.64±1.06	6.14±0.89	10.24±1.82	5.55±0.78	7.23±0.82	6.77±1.41	7.32±1.29
	Range	4.25-12.95	3.15-9.33	4.05-7.45	3.49-9.49	4.12-8.54	6.31-16.11	1.39-9.49	5.09-10.02	1.59-9.69	4.22-11.63

MRPs in pet foods

- Canned>pelleted>extruded
- MRPs can originate from

    raw materials (incl. palatability enhancer)

    processing the food

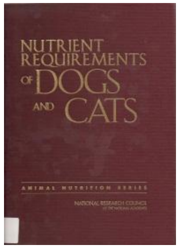
    drying

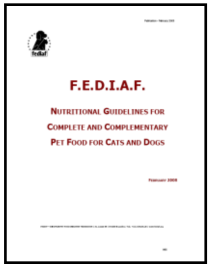
    storage

- LAL is not different between pet food types

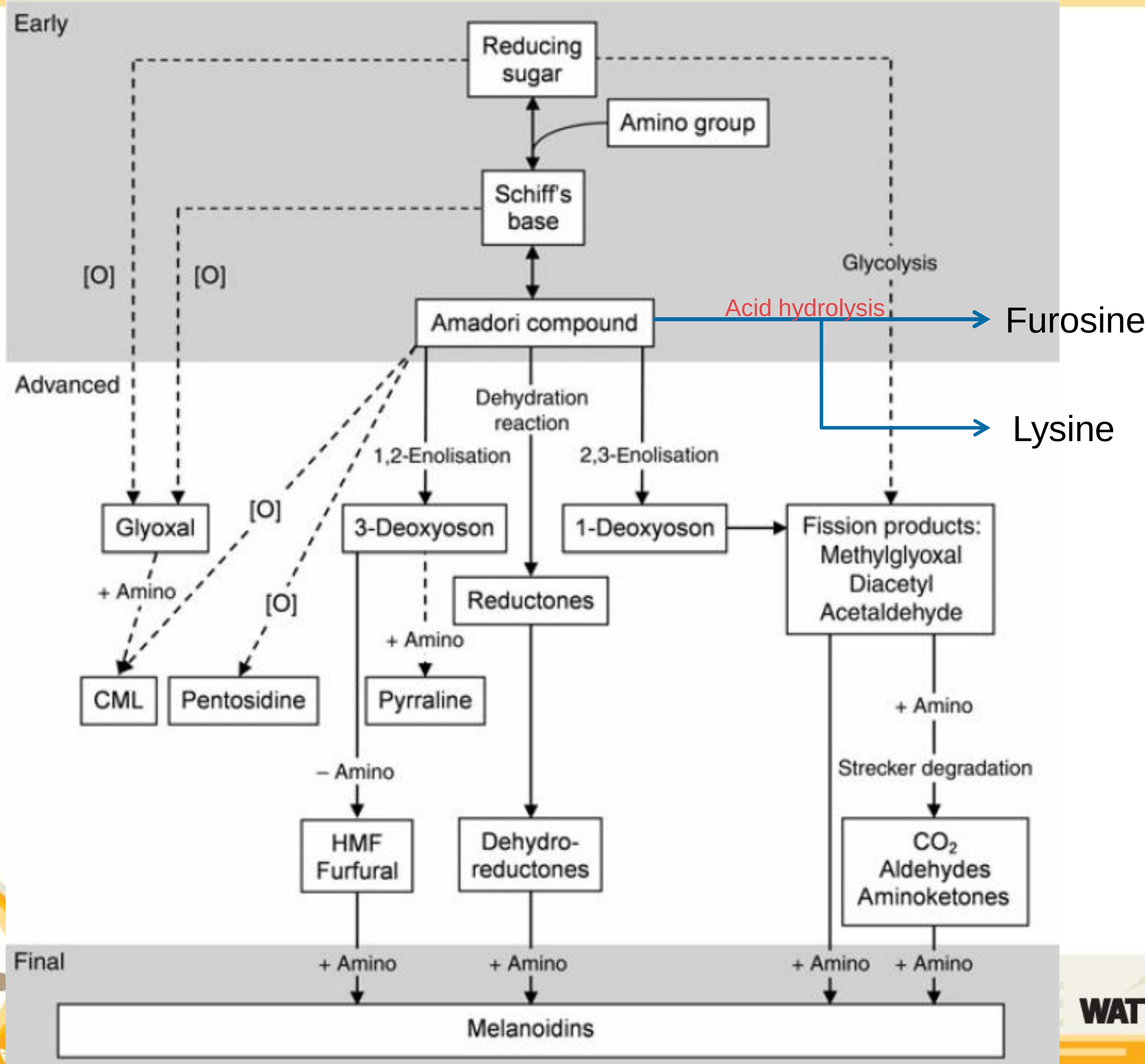
Petfood formulation

- FEDIAF or AAFCO tables are commonly used to meet minimum nutrient requirement





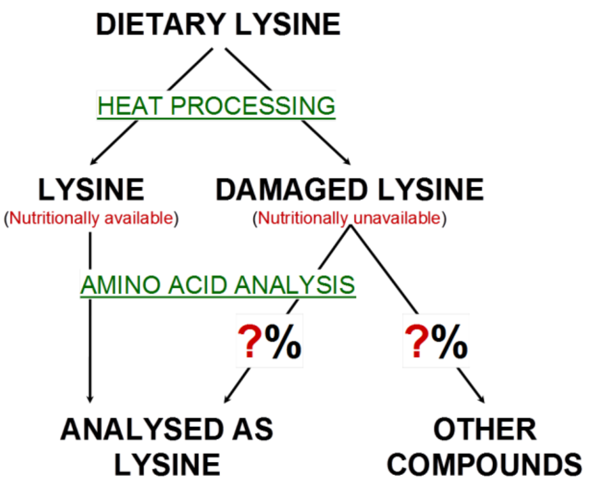
- Processing can have a major impact on the lysine content

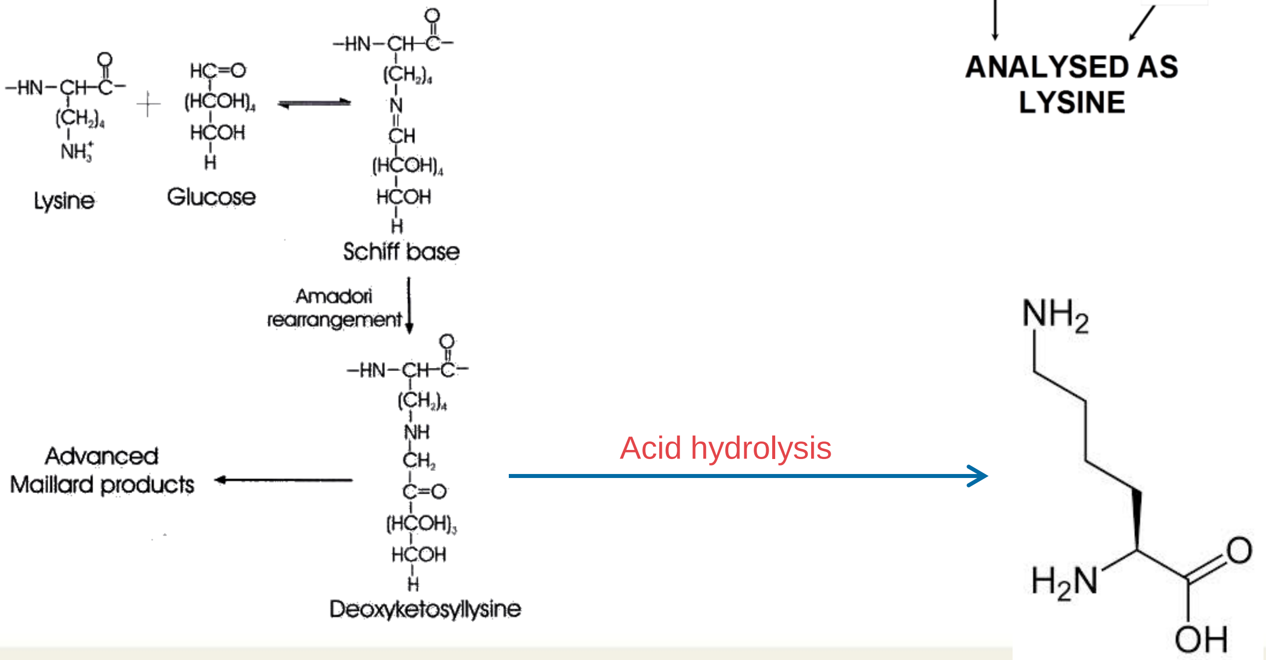


Early
Reducing sugar
Amino group
Schiff's base
[O]
[O]
Glycolysis
Amadori compound
Acid hydrolysis
Furosine
Lysine
Advanced
Dehydration reaction
1,2-Enolisation
2,3-Enolisation
Glyoxal
[O]
3-Deoxyoson
1-Deoxyoson
Fission products: Methylglyoxal Diacetyl Acetaldehyde
+ Amino
[O]
Reductones
+ Amino
CML
Pentosidine
Pyrraline
+ Amino
Strecker degradation
– Amino
HMF Furfural
Dehydro-reductones
CO_2 Aldehydes Aminoketones
Final
+ Amino
+ Amino
+ Amino
+ Amino
Melanoidins
Petfood Forum
WATT GLOBAL MEDIA

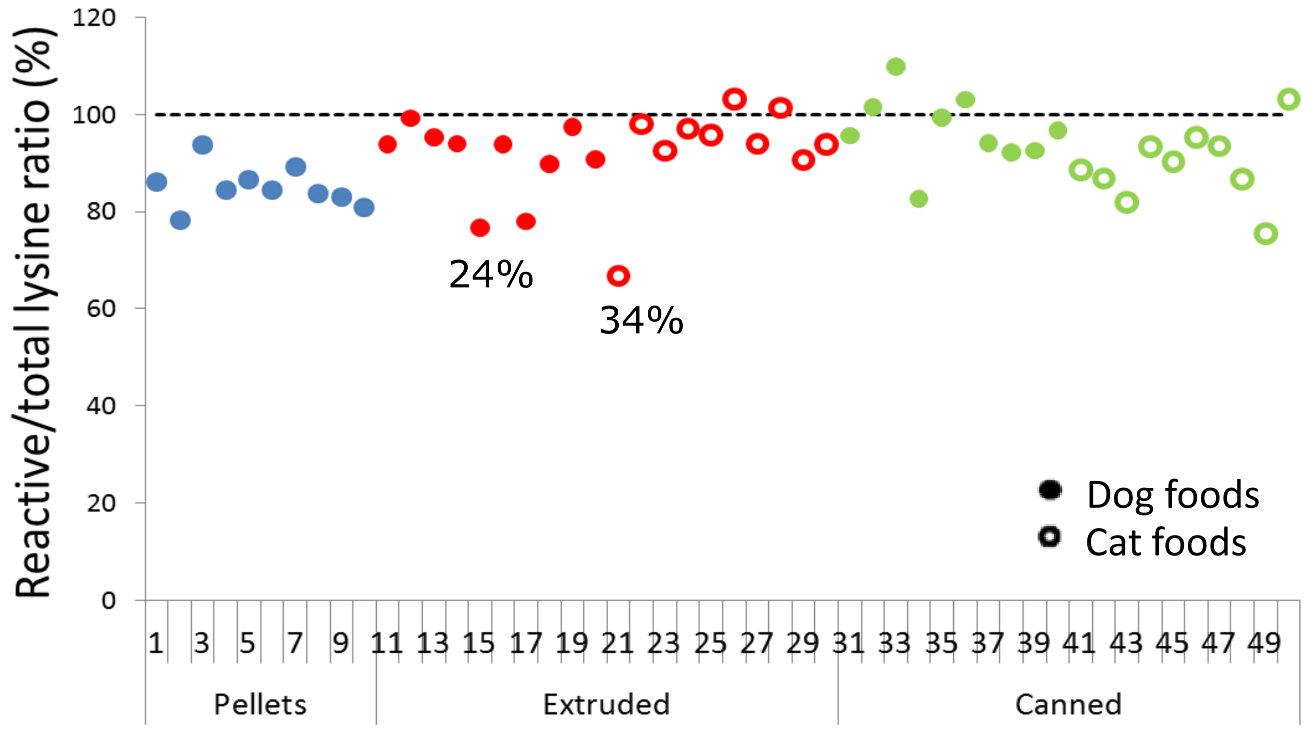
Total *vs.* reactive lysine

- Reactive lysine = lysine with a free ε–amino group

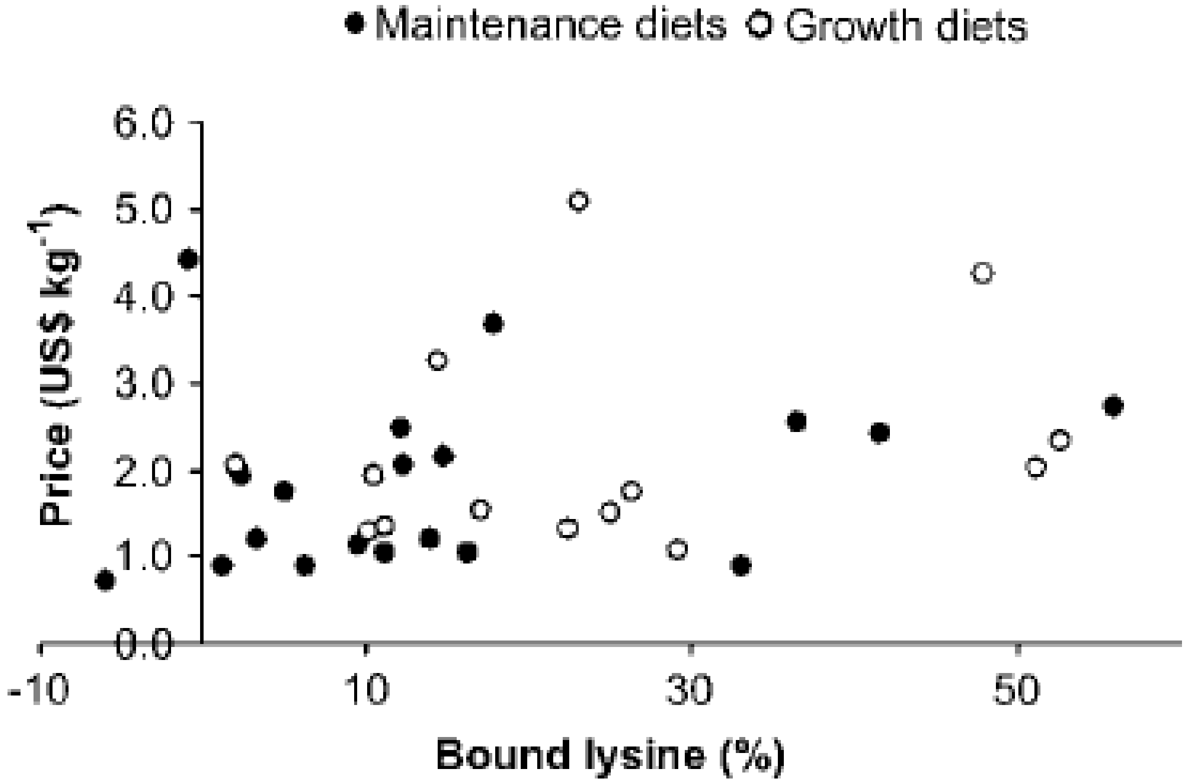




Total *vs.* reactive lysine in pet foods

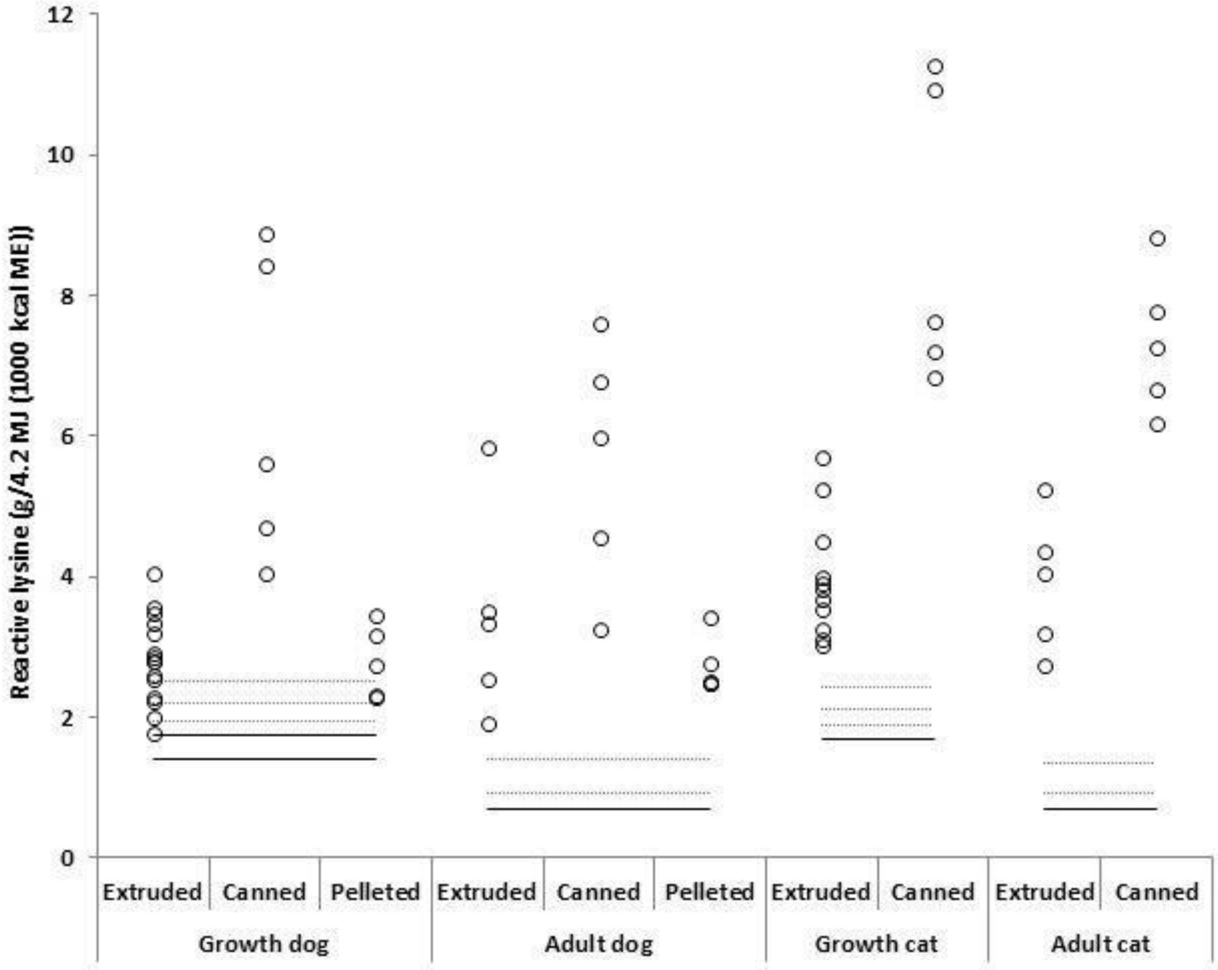


Bound lysine *vs.* pet food price

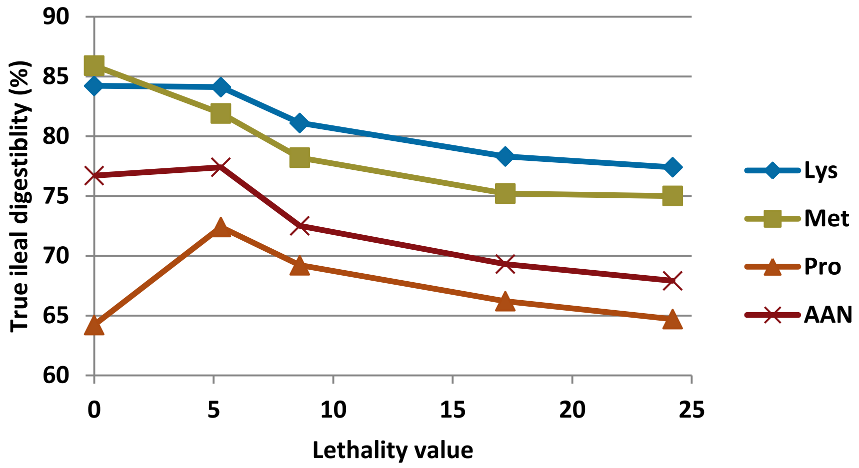


Williams et al. (2006) J Nutr 136, 1998S-2000S

Reactive lysine *vs.* minimal requirements



Processing a moist pet food



Lethality value = time equivalent of a heating process to destroy microorganisms at 121°C.

	Lethality value									
Chemical component	0		5.3		8.6		17.2		24.2	
Crude protein	567		564		563		568		565	
Total lysine	36.2	(6.4)[a]	38.1	(6.7)	39.1	(6.9)	39.2	(6.9)	39.2	(6.9)
FDNB-reactive lysine[b]	32.9	(5.8)	31.2	(5.5)	32.3	(5.7)	34.1	(6.0)	32.4	(5.7)
OMIU-reactive lysine	31.9	(5.6)	32.9	(5.8)	34.1	(6.1)	32.7	(5.8)	32.4	(5.7)

[a]The value in parentheses is the percentage of the crude protein content.
[b]The correction factor used for the FDNB method was 1.05.

Drying a dry canine food

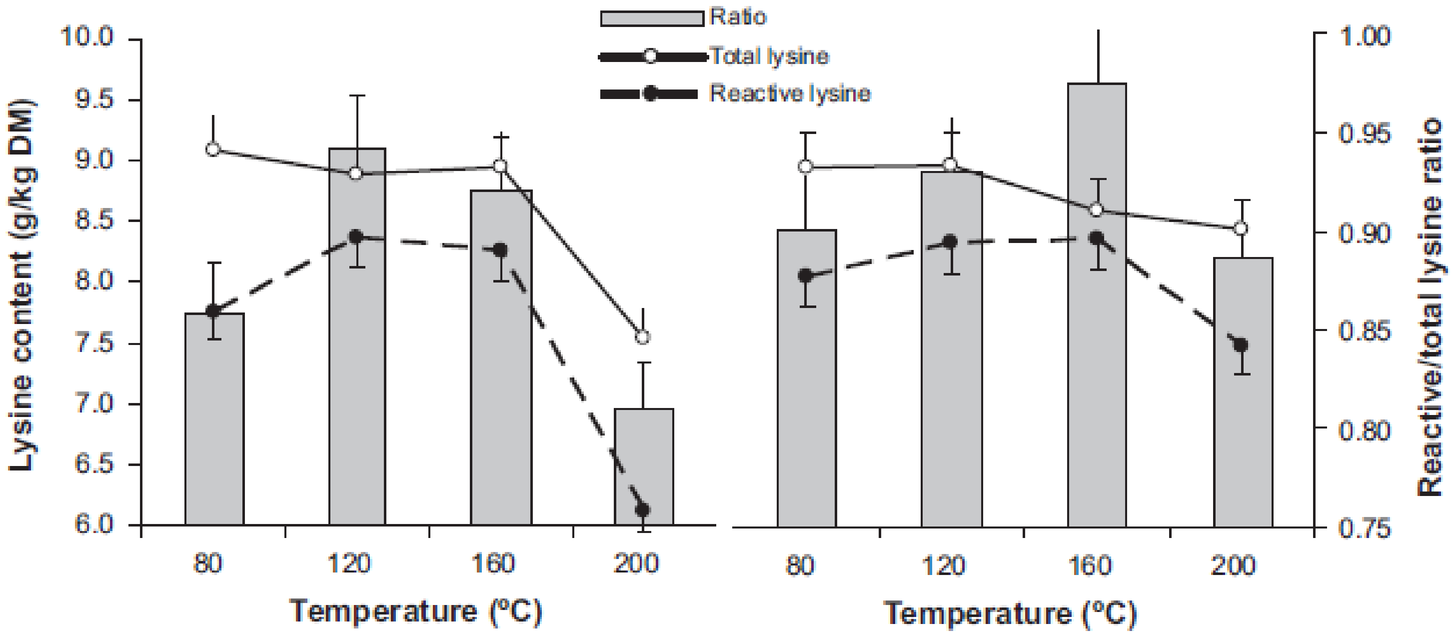


Fig. 1. Effect of drying temperature on total and reactive lysine content in a diet extruded using a die opening of 4 mm (left) or 8 mm (right).

Effects of drying temperature and time of a canine diet extruded with a 4 or 8 mm die on physical and nutritional quality indicators

Q.D. Tran[1], W.H. Hendriks, A.F.B. van der Poel*

Animal Nutrition Group, Department of Animal Sciences, Wageningen University, Marijkeweg 40, 6709 PG Wageningen, The Netherlands

Steam pelleting of pet foods

- Study design

  Mash vs. Pelleted diet

  Three die sizes (45, 65, 80 mm), 2 temp (65, 90°C)

  Total lysine, reactive lysine, MRPs, pellet quality, ...)

- Results

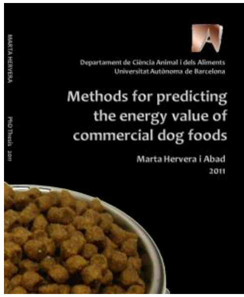
	Mash	Pelleted	Experimental pellets					
			5 x 45 mm		5 x 65 mm		5 x 80 mm	
			65°C	90°C	65°C	90°C	65°C	90°C
Total lysine (TL)	10.81 ± 0.20	10.71 ± 0.26	10.60	10.64	10.76	10.55	10.78	10.93
Reactive lysine (RL)	9.55 ± 0.38	9.7 ± 0.39	9.59	9.35	9.73	9.57	9.96	10.00
RL/TL ratio	0.88	0.90	0.90	0.88	0.90	0.91	0.92	0.92

Pet food ingredients

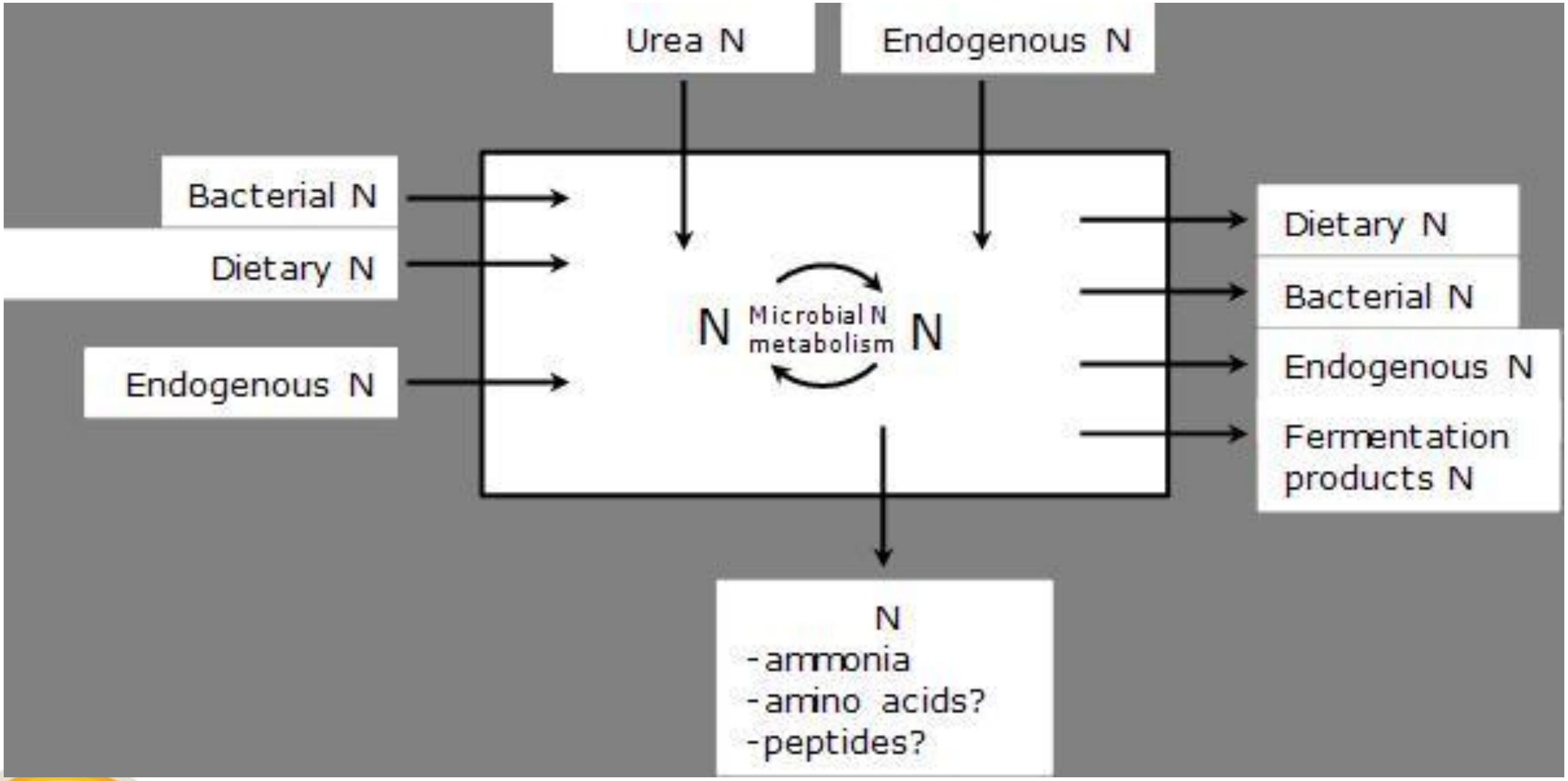
Ingredient	Reactive/Total lysine ratio
Soybean meal	0.77-1.00
Fish meal	0.90-0.99
Chicken meat	0.78
Meat meal	0.77-0.84
Meat and bone meal	0.64-0.96
Maize	0.56-0.75
Rice	0.83
Wheat	0.78-0.90

Protein digestibility in dogs

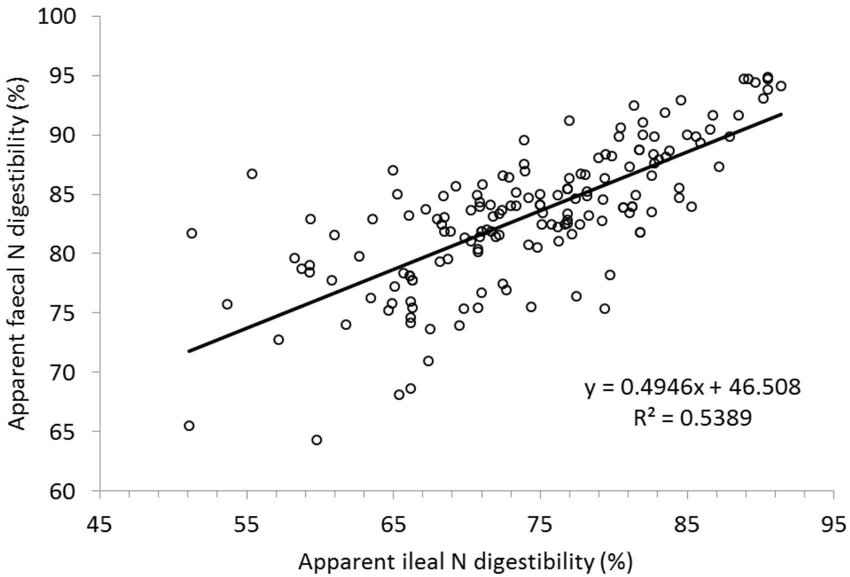
- Use of total tract method (apparent faecal digestibilities)
  - CP digestibility in pet foods range from 71.0-92.0 (mean 82.4%)
- Amino acids are absorbed in the small intestine, not the large intestine
- Amino acids are fermented in the large intestine



Fermentation in the large intestine



Protein digestibility in dogs



Comparison of ileal and total tract nutrient digestibility of dry dog foods[1]

W. H. Hendriks,*†[2] D. G. Thomas,‡ G. Bosch,* and G. C. Fahey Jr.§

*Animal Nutrition Group, Wageningen University, 6700 AH, Wageningen, The Netherlands; †Faculty of Veterinary Medicine, Utrecht University, 3508 TD, Utrecht, The Netherlands; ‡Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand; and §Department of Animal Sciences, University of Illinois, Urbana 61801

	Apparent digestibility		
Item	Ileal	Total tract (fecal)	Difference
DM, %	75.1 (64.4 to 80.7)	81.2 (78.5 to 84.8)	+6.2
OM, %	79.4 (69.5 to 85.4)	85.3 (82.2 to 87.6)	+5.9
CP, %	76.2 (66.2 to 83.3)	81.9 (78.1 to 83.9)	+5.7
Crude fat, %	96.5 (93.9 to 98.2)	92.4 (90.2 to 95.7)	−4.1
Carbohydrates,[1] %	88.9 (81.7 to 95.9)	95.5 (92.1 to 99.7)	+6.5

[1]Determined by OM – CP – crude fat.

Protein digestibility in dogs

Item	Dry canine maintenance food[1]				
	D_{19}	D_{21}	D_{23}	D_{26}	D_{30}
DM, %	84.8	92.0	92.1	93.1	93.0
OM, % DM	90.0	94.8	93.5	92.5	91.5
CP, % DM	24.3	26.5	24.6	29.0	32.7
Crude fat, % DM	7.2	10.8	8.9	12.4	18.0
Carbohydrates[2], % DM	58.5	57.5	59.9	51.1	40.7
Indispensable AA, % DM					
Arg	1.52	1.76	1.51	1.41	2.11
His	0.50	0.60	0.52	0.55	0.80
Ile	0.86	0.93	0.83	0.92	1.19
Leu	1.68	1.83	1.67	2.51	2.23
Lys	1.09	1.39	1.20	1.38	1.96
Met	0.33	0.49	0.45	0.60	0.76
Phe	0.98	1.04	0.90	1.19	1.20
Thr	0.77	0.87	0.82	0.90	1.26
Val	1.02	1.17	1.05	1.22	1.50
Dispensable AA, % DM					
Ala	1.29	1.69	1.48	2.00	2.18
Asp	2.29	2.43	2.15	2.02	2.80
Cys	0.37	0.37	0.36	0.43	0.37
Glu	4.16	4.10	3.60	4.41	4.26
Gly	1.31	1.75	1.50	1.66	2.46
Pro	1.61	1.66	1.55	1.83	1.78
Ser	0.97	1.02	0.90	1.04	1.17
Tyr	0.73	0.83	0.71	0.97	1.00
N of AA, % DM	3.26	3.67	3.23	3.70	4.48
Reactive Lys, % DM	0.93	0.89	1.03	1.13	1.15

[1]Values denote the CP content of the diet (D) as specified on the label.

[2]Determined by OM – CP – crude fat.

Total tract *vs.* ileal digestiblity

Item	Apparent digestibility		Difference
	Ileal	Total tract (fecal)	
Indispensable AA, %			
Arg	87.3	91.7	+4.4
His	61.4	78.7	+17.3
Ile	77.7	80.6	+2.9
Leu	79.4	84.9	+5.5
Lys	76.8	81.6	+4.9
Met	82.6	83.8	+1.2
Phe	80.3	84.6	+4.3
Thr	62.0	79.0	+17.0
Val	72.3	79.6	+7.3
Dispensable AA, %			
Ala	77.7	81.6	+3.9
Asp	67.0	82.0	+15.0
Cys	56.5	75.3	+18.8
Glu	81.6	87.1	+5.5
Gly	73.1	83.7	+10.6
Pro	78.8	88.2	+9.4
Ser	69.0	82.6	+13.6
Tyr	77.2	82.8	+5.6
N of AA	76.7	84.6	+8.0

Total tract *vs.* ileal digestiblity

	Apparent Lys digestibility, %					Standardized Lys digestibility, %				
Diet[2]	Total	Reactive	Difference	SEM	*P*-value	Total	Reactive	Difference	SEM	*P*-value
D_{19}	60.2	74.8	14.4	2.6	0.005	64.2	79.5	15.3	2.6	0.004
D_{21}	82.7	85.8	3.1	2.2	0.033	85.9	90.9	5.0	2.2	0.007
D_{23}	83.5	89.4	5.9	0.8	0.006	87.2	93.7	6.5	0.8	0.005
D_{26}	81.9	89.4	7.5	2.0	0.021	85.1	93.0	7.9	2.0	0.018
D_{30}	75.4	80.4	5.0	1.0	0.016	77.7	84.3	6.6	1.0	0.007

[1]Corrected for endogenous losses as determined using a protein-free diet (Hendriks et al., 2002b).

[2]Values denote the CP content of the diet (D) as specified on the label.

Conclusions

- Commercial pet foods contain high concentrations of Maillard reaction products
- Cats and dogs consume significant amounts of MRPs daily (effects on health ?)
- Reactive lysine is generally lower than total lysine, affecting nutritional value of pet foods
- The pelleting process does not appear to promote MRP formation (ingredient selection, storage)

Take home messages

- Importance of protein for optimal nutrition of cats and dogs is increasing
- Pet food processing has a major impact on the protein quality of pet foods
- Total tract digestiblity provides overestimates of protein quality

I hope he will say,
“dogs should eat more”